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(54) **TWO-STAGE COMBUSTOR FOR GAS TURBINE ENGINE**

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CPC ... **F23R 3/16** (2013.01); **F23R 3/06** (2013.01);
F23R 3/26 (2013.01); **F23R 3/346** (2013.01)

(58) **Field of Classification Search**
CPC F23R 3/002; F23R 3/16; F23R 3/346;
F23R 3/46; F23R 3/50
USPC 60/751–760, 740
See application file for complete search history.

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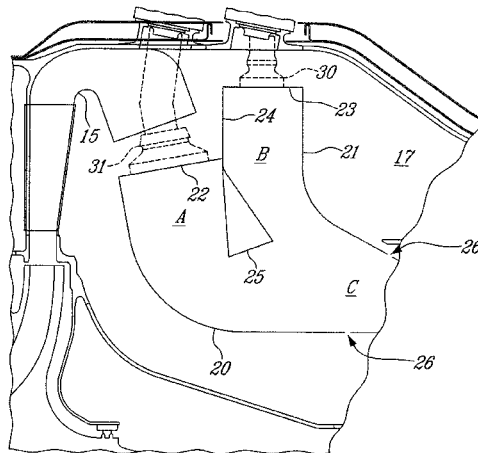
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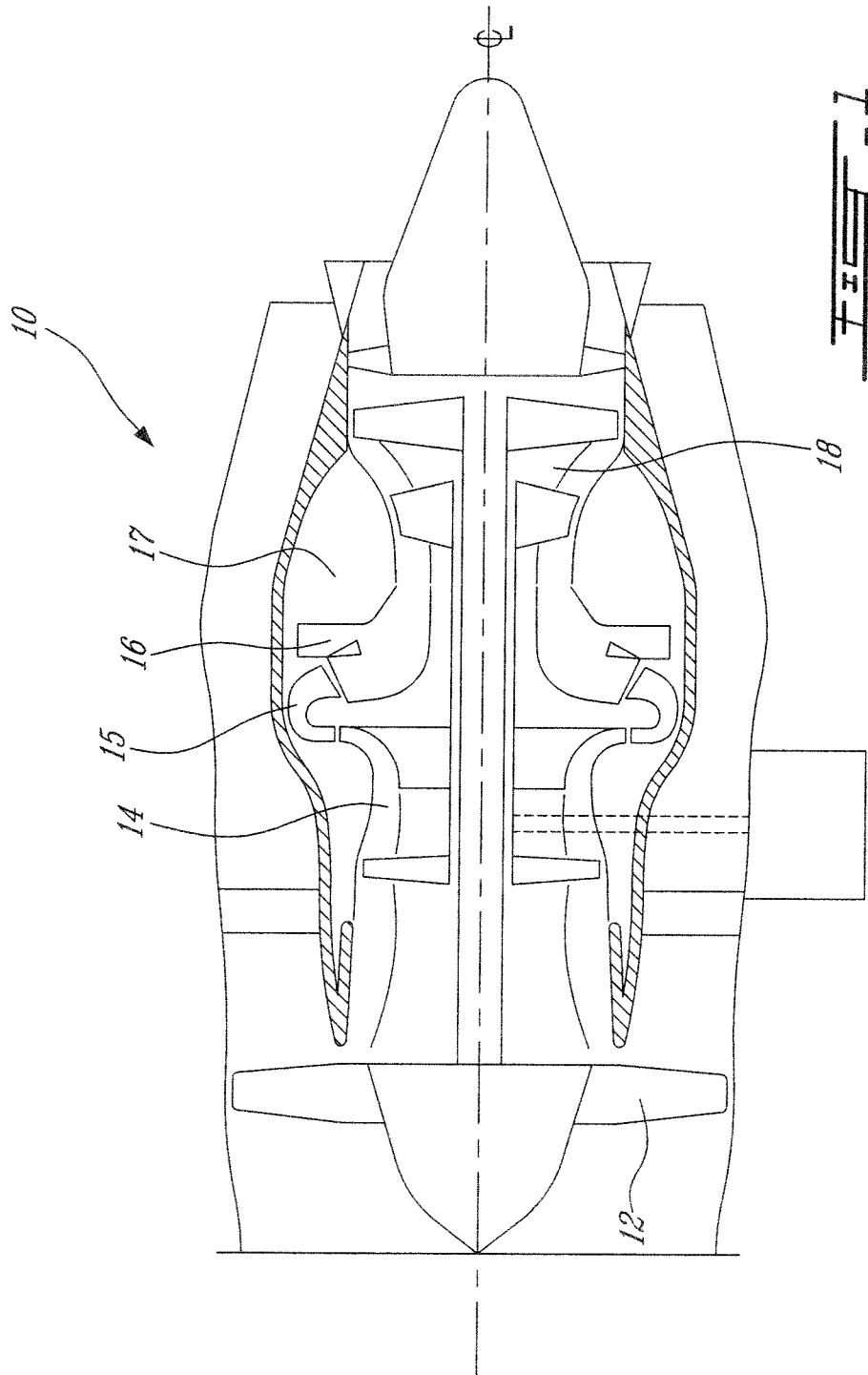
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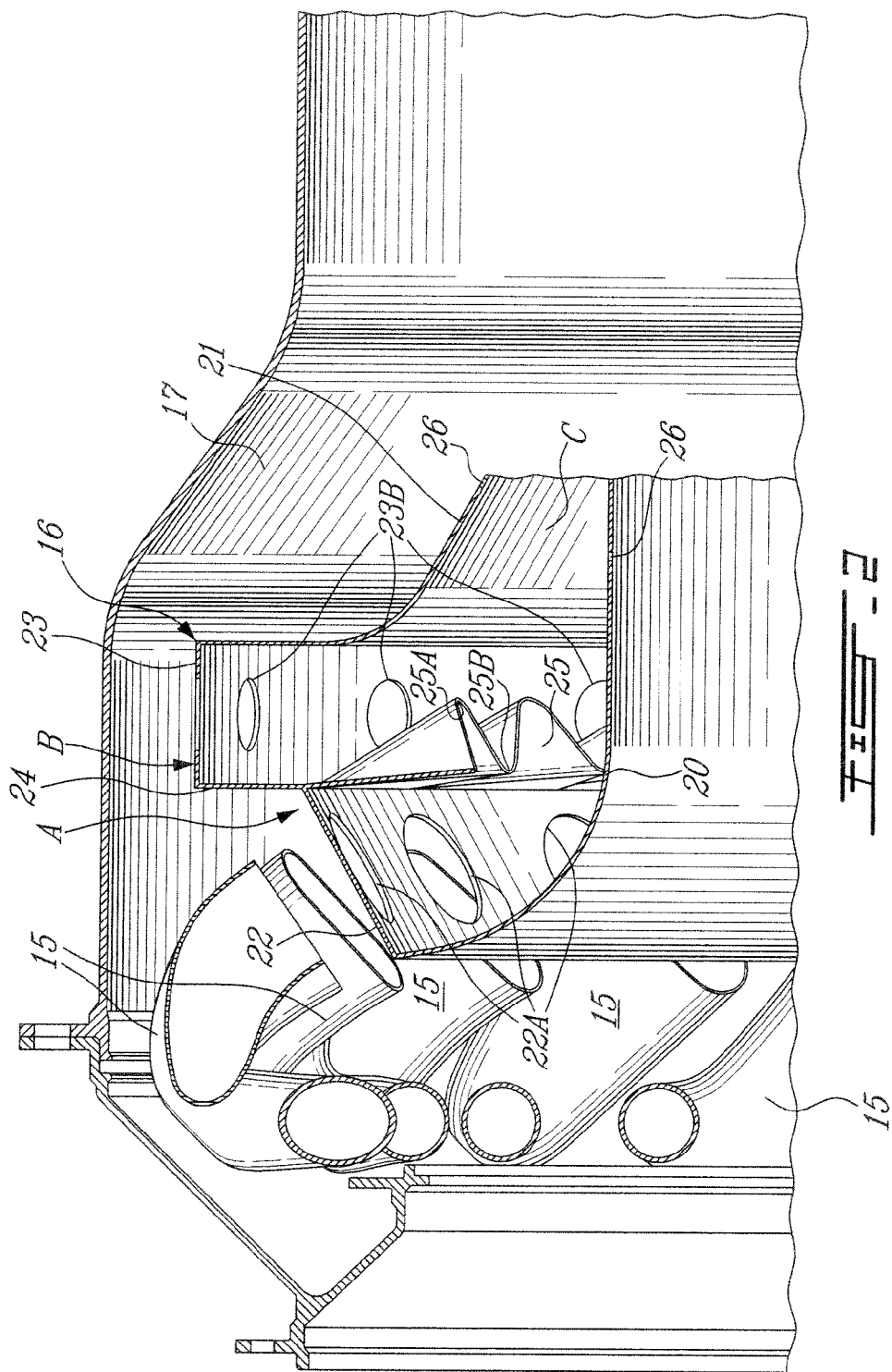
(57) **ABSTRACT**

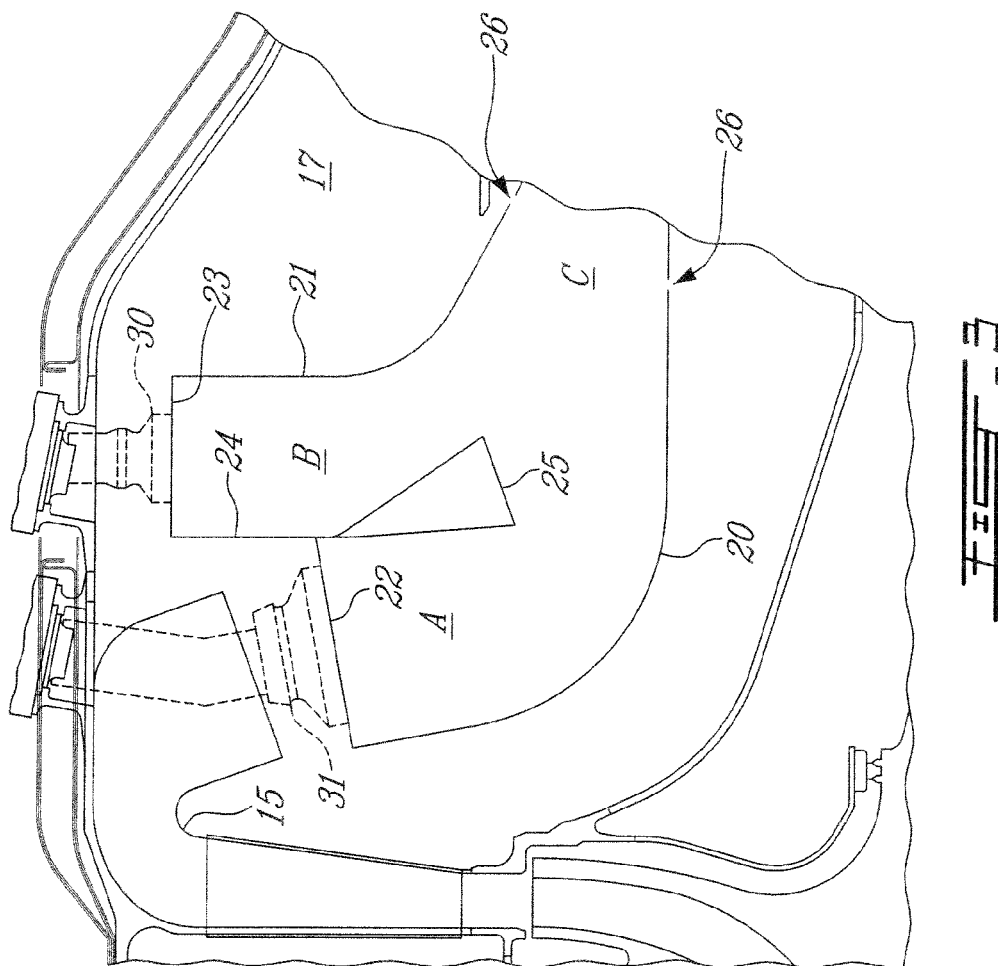
A combustor for a gas turbine engine comprises an inner annular liner wall and an outer annular liner wall cooperating to form a combustion chamber of the combustor. A first dome wall has a circumferential array of first fuel injection bores. A second dome wall has a circumferential array of second fuel injection bores. An intermediate wall extends between the first dome wall and the second dome wall. A first combustion stage is defined by the inner liner wall forward end, the first dome wall and the intermediate wall. A second combustion stage is defined at least by the outer liner wall forward end, the second dome wall and the intermediate wall, the first combustion stage communicating with the first fuel injection bores, the second combustion stage communicating with the second fuel injection bores.

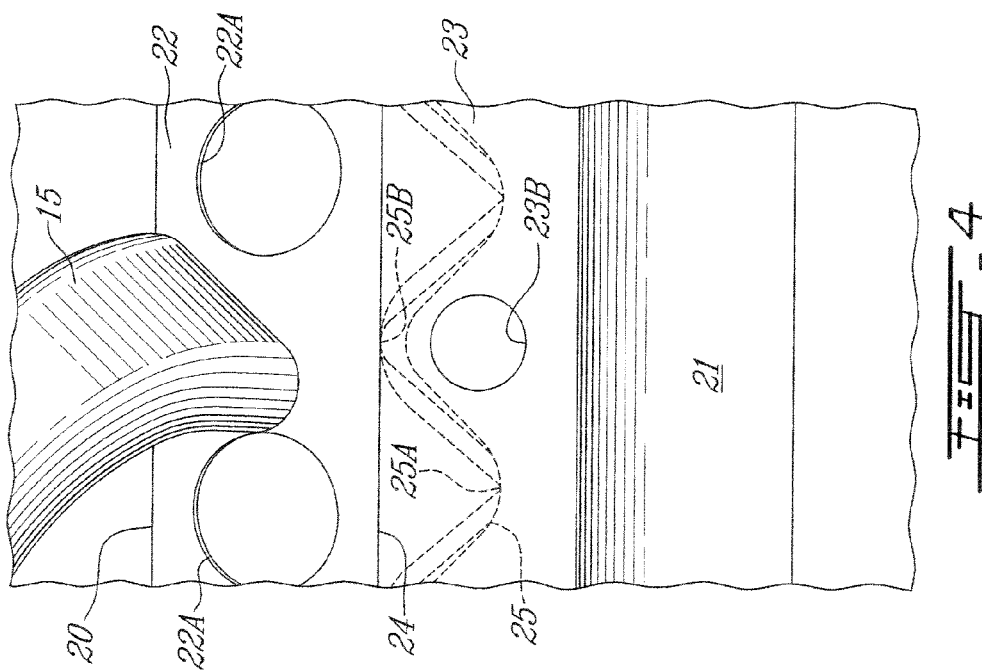
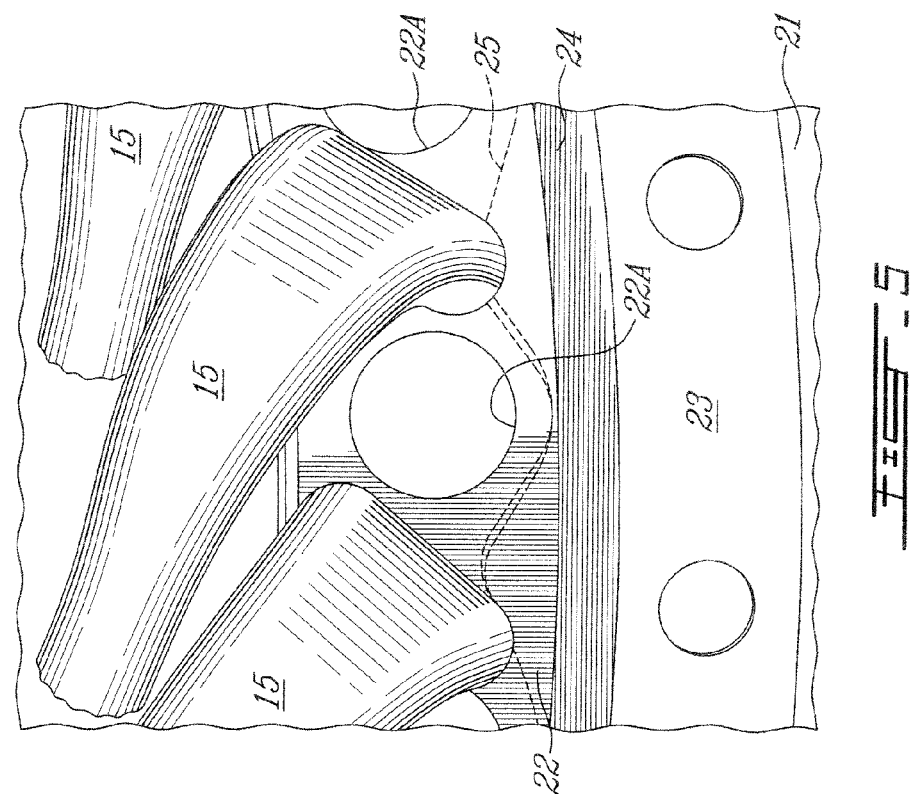
18 Claims, 4 Drawing Sheets











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TWO-STAGE COMBUSTOR FOR GAS TURBINE ENGINE

TECHNICAL FIELD

The application relates generally to gas turbine engines and, more particularly, to two-stage combustors.

BACKGROUND OF THE ART

In two-stage combustors, the combustor is comprised of two sub-chambers, one for the pilot stage of the burner, and the other for the main stage of the burner. The pilot stage operates the engine at low power settings, and is kept running at all conditions. The pilot stage is also used for operability of the engine to prevent flame extinction. The main stage is additionally operated at medium- and high-power settings. The arrangement of two-stage combustors involves typically complex paths, and may make avoiding dynamic ranges with their increased-complexity geometry more difficult. Also, problems may occur in trying to achieve a proper temperature profile. Finally, durability has been problematic.

SUMMARY

In one aspect, there is provided a combustor for a gas turbine engine, the engine having a central axis, the combustor comprising: an inner annular liner wall having an axially forward end generally radially oriented, the inner annular liner wall curving into an axial orientation as it extends in an aft direction to an axially aft end of the inner liner; an outer annular liner wall having an axially forward end generally radially oriented, the outer annular liner wall curving into an axial orientation as it extends in an aft direction to an axially aft end of the outer liner, with the inner annular liner wall and the outer annular liner wall spaced apart and cooperating to form a combustion chamber of the combustor; a first dome wall extending generally axially adjacent to the inner annular liner wall and circumscribing the forward end on the inner liner, the first dome wall having a circumferential array of first fuel injection bores radially extending through the first dome wall; a second dome wall extending generally axially adjacent to the outer annular liner wall and circumscribing the forward end of the outer liner, the second dome wall having a circumferential array of second fuel injection bores radially extending through the second dome wall; and an intermediate wall extending between the first dome wall and the second dome wall and, a first combustion stage defined at least by the inner liner wall forward end, the first dome wall and the intermediate wall, a second combustion stage defined at least by the outer liner wall forward end, the second dome wall and the intermediate wall, the first combustion stage communicating with the first fuel injection bores, the second combustion stage communicating with the second fuel injection bores.

In a second aspect, there is provided a gas turbine engine comprising: a casing defining a plenum; a combustor within the plenum comprising: an inner annular liner wall having an axially forward end generally radially oriented, the inner annular liner wall curving into an axial orientation as it extends in an aft direction to an axially aft end of the inner liner; an outer annular liner wall having an axially forward end generally radially oriented, the outer annular liner wall curving into an axial orientation as it extends in an aft direction to an axially aft end of the outer liner, with the inner annular liner wall and the outer annular liner wall spaced apart and cooperating to form a combustion chamber of the

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combustor; a first dome wall extending generally axially adjacent to the inner annular liner wall and circumscribing the forward end on the inner liner, the first dome wall having a circumferential array of first fuel injection bores radially extending through the first dome wall; a second dome wall extending generally axially adjacent to the outer annular liner wall and circumscribing the forward end of the outer liner, the second dome wall having a circumferential array of second fuel injection bores radially extending through the second dome wall; and an intermediate wall extending generally radially between the first dome wall and the second dome wall and, a first combustion stage defined at least by the inner liner wall forward end, the first dome wall and the intermediate wall, a second combustion stage defined at least by the outer liner wall forward end, the second dome wall and the intermediate wall, the first combustion stage communicating with the first fuel injection bores, the second combustion stage communicating with the second fuel injection bores; a compressor diffuser having at least one outlet within the plenum; and fuel injectors and/or valves disposed in communication the fuel injection bores.

Further details of these and other aspects of the present invention will be apparent from the detailed description and figures included below.

DESCRIPTION OF THE DRAWINGS

Reference is now made to the accompanying figures, in which:

FIG. 1 is a schematic cross-sectional view of a turbofan gas turbine engine with a two-stage combustor in accordance with the present disclosure;

FIG. 2 is an enlarged sectional view, fragmented, of the two-stage combustor of the present disclosure;

FIG. 3 is a schematic view of the two-stage combustor of FIG. 2, with diffusers and staging valves;

FIG. 4 is an enlarged perspective view of end walls of the two-stage combustor, showing an arrangement between a lobed mixer wall and aft injection ports; and

FIG. 5 is an enlarged perspective view of end walls of the two-stage combustor, showing an arrangement between a lobed mixer wall and fore injection ports.

DETAILED DESCRIPTION OF EMBODIMENTS

FIG. 1 illustrates a turbofan gas turbine engine 10 of a type preferably provided for use in subsonic flight, generally comprising in serial flow communication a fan 12 through which ambient air is propelled, a multistage compressor 14 for pressurizing the air, a plurality of curved radial diffuser pipes 15 in this example, a combustor 16 in which the compressed air is mixed with fuel and ignited for generating an annular stream of hot combustion gases, a plenum 17 defined by the casing and receiving the radial diffuser pipes 15 and the combustor 16, and a turbine section 18 for extracting energy from the combustion gases. The combustor 16 is a two-stage combustor in accordance with the present disclosure.

Referring to FIG. 2, the combustor 16 of the present disclosure is shown in greater detail. The combustor 16 has an annular geometry, with an inner liner wall 20, and an outer liner wall 21 concurrently defining the combustion chamber therebetween. The inner liner wall 20 has a fore end oriented generally radially relative to the engine centerline, liner wall 20 curving into an axial orientation relative to the engine centerline. Likewise, the outer liner wall 21 has a fore end oriented generally radially relative to the engine centerline,

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with the outer liner wall curving into an oblique orientation relative to the engine centerline.

A dome interrelates the inner liner wall **20** to the outer liner wall **21**. The dome is the interface between air/fuel injection components and a combustion chamber. The dome has a first end wall **22** (i.e., dome wall) sharing an edge with the inner liner wall **20**. The first end wall **22** may be in a non-parallel orientation relative to the engine centerline. Injection bores **22A** are circumferentially distributed in the first end wall **22**.

A second end wall **23** (i.e., dome wall) of the dome shares an edge with the outer liner wall **21**. The second end wall **23** may be in a generally parallel orientation relative to the engine centerline, or in any other suitable orientation. Injection bores **23B** are circumferentially distributed in the first end wall **23**. In the illustrated embodiment, the first end wall **22** may be wider than the second end wall **23**.

An intermediate wall **24** of the dome may join the first end wall **22** and the second end wall **23**, with the second end wall **23** being positioned radially farther than the first end wall **22** (by having a larger radius of curvature than that of the first end wall **22** relative to the engine centerline). The intermediate wall **24** may be normally oriented relative to the engine centerline. In this example, mixing features extend into the combustion chamber from the dome walls. The mixing features may be a mixer wall **25** extending from the intermediate wall **24** and projects into an inner cavity of the combustor **16**. The mixer wall **25** may have a lobed annular pattern, as illustrated in FIG. 2, with a succession of peaks and valleys along a circumference of the mixer wall **25**. The lobed mixer wall **25** in between the stages can be made out of composite materials (e.g. CMC) or metal. Although not shown, the lobed mixer wall **25** may be cooled by conventional methods (i.e., louvers, effusion and/or back side cooling).

Accordingly, as shown in FIGS. 2 and 3, the combustor **16** comprises a pair of annular portions, namely A and B, merging into an aft portion C of the combustor **16**. The annular portion A is defined by the inner liner wall **20**, the first end wall **22** and a fore surface of the mixer wall **25**. The annular portion B is defined by the outer liner wall **21**, the second end wall **23**, the intermediate wall **24**, and an aft surface of the mixer wall **25**. Dilution ports **26** may be defined in the liners of the aft portion C, to trim the radial profile of the combustion products.

Either one of the annular portions A and B may be used for the pilot stage, while the other of the annular portions A and B may be used for the main combustion stage. Referring to FIG. 3, as an example, the annular portion B is used for the pilot stage. In this example, the main combustion stage, represented by the annular portion A, has a larger volume than the pilot stage. Moreover, in this example, the main combustion stage is entirely axially forward of the second combustion stage.

Accordingly, injectors **30** are schematically illustrated as being mounted to the combustor outer case and as floating on the annular portion B, in register with respective floating collars at injection bores **23B**, for the feed of plenum air and fuel to the annular portion B of the combustor **16**. The annular portion A is used as the main stage in the case of having only fuel staging. The injectors **31** for annular portion A may have the same attachment arrangement as the injectors for the annular portion B. In the case of air staging, the annular portion A could act as the pilot section if it is considered convenient. Staging valves can be located in either location and, at the same time, they can act as support for the combustor, as well as acting as staging valves and fuel nozzle/swirlers.

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Referring to FIG. 4, the injection bores **23B** of the annular portion B (with injectors **30** removed for illustration purposes) are shown as being in radial register with valleys of the lobed mixer wall **25**. Referring to FIG. 5, the injection bores **22A** of the annular portion A (with staging valves/injectors **31** removed for illustration purposes) are shown as being in radial register with valleys of the lobed mixer wall **25**. Therefore, the injection bores **22A** and **23B** are circumferentially offset from one another, as shown in FIGS. 4 and 5. As shown in FIGS. 2 and 3, the injection bores are also radially offset from one another by reason of the larger radius of the second end wall **23**. Moreover, as shown in both FIGS. 4 and 5, ends of passages of the diffuser pipes **15** are located between the injection bores **22A** (i.e., in circumferential offset), but in circumferential alignment with the bores **23B**. Therefore, there is a clearance opposite the injection bores **22A**, thus defining a volume for the installation and presence of injectors or staging valves.

Referring to FIG. 2, bottom edges **25A** of each of the valleys of the mixer wall **25** in the annular portion A are approximately normal to the first end wall **22**, at intersections therebetween. Likewise, bottom edges of each of the valleys of the mixer wall **25B** are approximately normal to the second end wall **23**, at intersections therebetween. In both cases, other orientations between valleys and end walls are also possible.

The arrangement of the combustor **16** may be well suited for engines with centrifugal compressors, and may be used for fuel and/or air staging since the front end of the combustor may be readily accessible and close to the outer case. This could enable the use of actuators for controlling air splits or flow splits on the outside of the combustor chamber, since the mechanisms can be placed outside the plenum **17**.

The above description is meant to be exemplary only, and one skilled in the art will recognize that changes may be made to the embodiments described without departing from the scope of the invention disclosed. Any suitable liner configurations and dome shapes may be employed. The intermediate wall may have any suitable configuration, and need not be a lobed mixer but may have other mixing features or no mixing function at all. The fuel nozzles may be of any suitable type and provided in any suitable orientation. The fuel nozzles may be fed from common stems or from a common source. Any suitable diffuser arrangement may be used, and pipe type diffusers are not required nor is the radial arrangement depicted in the above examples. For example, a vane diffuser may be provided in preference to a pipe diffuser. Where axial compression is provided, another suitable arrangement for diffusion may be provided. Still other modifications which fall within the scope of the present invention will be apparent to those skilled in the art, in light of a review of this disclosure, and such modifications are intended to fall within the appended claims.

What is claimed is:

1. A combustor for a gas turbine engine, the engine having a central axis, the combustor comprising:
 - an inner annular liner wall having an axially forward end generally radially oriented, the inner annular liner wall curving into an axial orientation as it extends in an aft direction to an axially aft end of an inner liner;
 - an outer annular liner wall having axially forward end generally radially oriented, the outer annular liner wall curving into an axial orientation as it extends in an aft direction to an axially aft end of an outer liner, with the inner annular liner wall and the outer annular liner wall spaced apart and cooperating to form a combustion chamber of the combustor;

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a first dome wall extending generally axially adjacent to the inner annular liner wall and circumscribing the forward end on the inner liner, the first dome wall having a circumferential array of first fuel injection bores radially extending through the first dome wall;

a second dome wall extending generally axially adjacent to the outer annular liner wall and circumscribing the forward end of the outer liner, the second dome wall having a circumferential array of second fuel injection bores radially extending through the second dome wall;

an intermediate wall extending between the first dome wall and the second dome wall and being an intermediate single wall wherein the second dome wall is spaced radially outward from the first dome wall and the first dome wall is connected to the intermediate wall at a location different than the second dome wall; and

a mixing feature defined by a single wall projecting into the combustion chamber from the intermediate wall, the single wall separating the first combustion stage from the second combustion stage;

wherein a first combustion stage is defined at least by the inner annular liner wall forward end, the first dome wall, and the intermediate single wall or mixing feature, a second combustion stage defined at least by the outer annular liner wall forward end, the second dome wall, and the intermediate single wall or mixing feature, the first combustion stage communicating with the first fuel injection bores, the second combustion stage communicating with the second fuel injection bores.

2. The combustor according to claim 1, wherein the intermediate wall is radially oriented.

3. The combustor according to claim 1, wherein the second dome wall has a radius of curvature larger than a radius of the first dome wall.

4. The combustor according to claim 1, wherein the first combustion stage is a main combustion stage and wherein the second combustion stage is a pilot combustion stage.

5. The combustor according to claim 4, wherein the main combustion stage has a volume larger than the pilot combustion stage.

6. The combustor according to claim 1, wherein the first dome wall is axially wider than the second dome wall.

7. The combustor according to claim 1, wherein the circumferential array of the first fuel injection bores is circumferentially offset from the circumferential array of the second fuel injection bores.

8. The combustor according to claim 1, wherein the first combustion stage is generally radially inwardly oriented.

9. The combustor according to claim 8, wherein the second combustion stage is radially inwardly oriented.

10. The combustor according to claim 1, wherein the first dome wall is in a non-parallel orientation relative to the central axis.

11. The combustor according to claim 1, wherein the second dome wall is a generally parallel orientation relative to the central axis.

12. The combustor according to claim 1, wherein the intermediate wall is in a normal orientation relative to the central axis.

13. The combustor according to claim 1, further comprising dilution ports in the inner annular liner wall and the outer annular liner wall downstream of the first combustion stage and of the second combustion stage.

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14. The gas turbine engine according to claim 1, wherein the first combustion stage is a main combustion stage and wherein the second combustion stage is a pilot combustion stage.

15. The gas turbine engine according to claim 1, wherein the single wall is a single integral annular piece.

16. A gas turbine engine comprising:

- a casing defining a plenum;
- a combustor within the plenum comprising:
 - an inner annular liner wall having an axially forward end generally radially oriented, the inner annular liner wall curving into an axial orientation as it extends in an aft direction to an axially aft end of an inner liner;
 - an outer annular liner wall having an axially forward end generally radially oriented, the outer annular liner wall curving into an axial orientation as it extends in an aft direction to an axially aft end of an outer liner, with the inner annular liner wall and the outer annular liner wall spaced apart and cooperating to form a combustion chamber of the combustor;
 - a first dome wall extending generally axially adjacent to the inner annular liner wall and circumscribing the forward end on the inner liner, the first dome wall having a circumferential array of first fuel injection bores radially extending through the first dome wall;
 - a second dome wall extending generally axially adjacent to the outer annular liner wall and circumscribing the forward end of the outer liner, the second dome wall having a circumferential array of second fuel injection bores radially extending through the second dome wall;
 - an intermediate wall extending generally radially between the first dome wall and the second dome wall and being an intermediate single wall wherein the second dome wall is spaced radially outward from the first dome wall and the first dome wall is connected to the intermediate wall at a location different than the second dome wall;
 - a mixing feature defined by a single wall projecting into the combustion chamber from the intermediate wall, the single wall separating the first combustion stage from the second combustion stage, wherein a first combustion stage is defined at least by the inner annular liner wall forward end, the first dome wall, and the intermediate single wall or mixing feature, a second combustion stage defined at least by the outer annular liner wall forward end, the second dome wall, and the intermediate single wall or mixing feature, the first combustion stage communicating with the first fuel injection bores, the second combustion stage communicating with the second fuel injection bores;
 - a compressor diffuser having at least one outlet within the plenum; and
 - fuel injectors and/or valves disposed in communication with the fuel injection bores.

17. The gas turbine engine according to claim 16, wherein the diffuser comprises a plurality of passages circumferentially distributed about the combustor, with the outlets of the diffuser passages being radially offset from the first fuel injection bores of the first dome wall.

18. The gas turbine engine according to claim 16, wherein the second fuel injection bore holes of the second dome wall are circumferentially aligned with the diffuser outlets.

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